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**VHF-FM PORTION OF THE SINGLE  
CHANNEL GROUND AND AIRBORNE  
RADIO SUBSYSTEM**

**CONCEPT FORMULATION PACKAGE  
APPENDIX IV  
COST & OPERATIONAL EFFECTIVENESS  
ANALYSIS**

**OCTOBER 1975**

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This appendix is a compilation of two separate and distinct cost and operational effectiveness analyses (COEA) which were conducted to evaluate the four alternatives recommended to satisfy the SINGGARS-V requirements.		

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**VHF-FM PORTION OF THE SINGLE  
CHANNEL GROUND AND AIRBORNE  
RADIO SUBSYSTEM**

**CONCEPT FORMULATION PACKAGE**

**APPENDIX IV  
COST & OPERATIONAL EFFECTIVENESS ANALYSIS**

**OCTOBER 1975**

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DEPARTMENT OF THE ARMY  
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## APPENDIX IV

### COST AND OPERATIONAL EFFECTIVENESS ANALYSIS

#### 1. INTRODUCTION.

(1) SINGGARS-V as a combat support system precludes direct translation of the classical measure of the force effectiveness as it is commonly applied to weapons systems which directly engage and destroy the enemy. The attempt to ascribe a quantifiable measure of force effectiveness for a SINGGARS-V alternative is further complicated by the lack of accurate data by which any given communications, e.g., a radio transmission, can be assigned a value relative to its impact on the conduct of the battle. Studies presently underway, such as the COMSEC Priorities Evaluation, may provide this type of information for use in subsequent analysis to support an ASARC II/DSARC II decision.

(2) Two distinct and separate cost and operational effectiveness analyses (COEA) were conducted to evaluate the four alternatives recommended to satisfy the SINGGARS-V requirements. The COEA performed by the TRADOC Systems Analysis Activity (TRANSANA) is at Annex A. The collateral analysis conducted for the SINGGARS Special Task Force by Decisions and Designs, Inc., (DDI) (Contract No. 00014-73-C-0149) is at Annex B.

b. Purpose. The purpose of this Appendix is to:

(1) Integrate the results of the evaluations at Annexes A and B;

(2) Incorporate additional cost information from the cost analysis brief (CAB) developed as a result of the Comptroller of the Army analysis of the ECOM Comptroller's independent parametric cost estimate (IPCE) and the baseline cost estimate (BCE) prepared by the Project Manager, SINGGARS;

(3) Provide consideration of the COMSEC costs and options which are available as a result of the radio alternative selected;

(4) Extend additional consideration to the implication of the postulated EW threat for the post-1985 time frame;

(5) Assess the impact of changing technology upon logistical support of the current family of SINGGARS-V equipment.

c. Definitions. Terms and acronyms used herein are contained in Annex A of Appendix I, TOD.

d. References. References are contained in Annex F of Appendix I, TOD.

#### 2. DISCUSSION.

a. Integration of the TRADOC and DDI evaluations.

(1) Both evaluations developed a figure of merit, or military value, for each alternative based upon performance characteristics and user requirements. Performance characteristics of each alternative were evaluated to gain a perspective as to the relative performance applicable to each alternative. It cannot be asserted that a difference in alternative scores is a direct or precise reflection of their relative effectiveness. The relationship between these scores, however, does provide an indication as to the alternative's performance and thereby its contribution to successful combat mission performance.

(2) The TRADOC COEA uses mathematical equations to quantify performance characteristics of each alternative, wherever possible. Subjective evaluations are made for those characteristics which could not be mathematically quantified. While these measures of performance were aggregated into common areas, there is visibility within the TRADOC model to permit comparison between the alternatives for each characteristic. Table IV-1 is a composite of the assessment developed by TRADOC for each candidate alternative. The Figures of Merit normalized to Alternative #1 (the base case) are displayed in Table IV-2. From an examination of Table IV-2, it can be inferred that Alternatives #3 and #4 offer significantly improved performance over the base case. Table

IV-3 shows the relationship of the alternatives based on weighting the relative performance indices (Table IV-2) for each method of ranking by the percent of equipment of each configuration deployed. (The percentage of equipment deployed by configuration is used because no enhancement to performance is realized by float equipment in storage.) Table IV-3 is in a form where a comparison can be made for the relative worth of the TRADOC and DDI evaluations.

(3) The DDI evaluation employed a methodology different from the TRADOC evaluation. Analysis of the user mission requirements was used to develop utility curves and functions to reflect the potential contribution of each alternative to the combat mission accomplishment. Visibility, within the DDI model is possible for each performance characteristic. Table IV-4 (Utility Summary) shows the aggregated overall military value for each alternative derived for subordinate major dimensions of value. Table IV-5, Relative Utility Summary, portrays the utility for each alternative normalized to the base case.

(4) A comparison of Tables IV-4 and IV-5 with Tables IV-1, IV-2 and IV-3 shows there is mutual agreement between the two COEA's in that Alternatives #3 and #4 offer enhanced performance over the base case in each evaluation.

#### b. Cost Considerations.

(1) During the conduct of the TRADOC COEA, the only cost estimates available for comparison were the 15-year life cycle cost estimates (LCCE). An IPCE and a BCE, derived from the LCCE and providing for the phasing in of costs over time, were developed by the Project Manager concurrent with the COEA effort. Table IV-6 summarizes the results of the LCCE, BCE and IPCE. These cost estimates do not include COMSEC or ECCM procurement costs.

(2) Table IV-7 shows the recommended Army cost position, derived from the Comptroller of the Army analysis of the IPCE and BCE.

(3) Table IV-8 shows the relative costs of the alternatives to the base case for each of the cost estimates listed in Tables IV-6 and IV-7.

(4) Performance values and cost estimates are combined to establish the relative worth for each alternative. These values are shown in Table IV-9 for both the TRADOC and the DDI evaluation models and are normalized to the base case, Alternative #1.

c. COMSEC Options and Costs. Both COEA's considered the capability of radio alternatives to accept a COMSEC module. Neither evaluation considered the COMSEC cost impact caused by the method of interfacing the radio and COMSEC module. This impact is driven by the radio capability to share circuitry and functions with the COMSEC device, thereby reducing the combined cost of a secured radio. ALTERNATIVE #4 is the only radio which is capable of accommodating these features through the use of the VANDAL TOP HAT module. This capability offers a significant potential cost savings (see Table IV-10) in COMSEC equipment procurement and support. The current Army VINSON program will provide Applique COMSEC modules in quantities equivalent to approximately 25% of the radio Authorized Acquisition Objective (AAO). LCCE's for all COMSEC options (including VINSON) procured to 100% of the radio AAO are listed in Table IV-10. As indicated, VINSON is two to three times as costly as the VANDAL COMSEC options. The following is the estimated cost avoidance which is available (only with Alternative #4) if the VANDAL TOP HAT is procured in lieu of the VANDAL Applique:

#### ESTIMATED SAVINGS

##### TOP HAT vs APPLIQUE

VANDAL Applique	\$ 752.9
VANDAL TOP HAT	\$ 554.8

$$\$198.1 \times 0.75 = \$148.5M$$

Based on this logic, the \$148.5M equates to an annual cost penalty of \$1.98M per year for each additional 1% of COMSEC modules procured against the radio AAO.

(1) Table IV-11 shows relative worth comparison of the alternatives based on recommended costs for 100% COMSEC implementation. (Costs are based on 25% VINSON and 75% VANDAL COMSEC equipments.)

(2) In addition to the COMSEC related cost benefits which Alternative #4 provides, there are two other considerations. The NSA is currently pursuing the VANDAL development as a TOP HAT module.

Redirection of the NSA efforts to provide VANDAL as an Applique unit could result in a schedule slip in the production of COMSEC modules or units. The undesirable aspects of a COMSEC Applique versus a TOP HAT module for operational and logistical support are also significant.

d. Electronic Warfare (EW) Threat Implications. The SINCGARS-V ROC summarized the user's requirement for ECCM protection by directing that the new SINCGARS-V equipment be designed to minimize susceptibility to hostile EW actions, i.e., electronic warfare support measures and electronic countermeasures. The EW threat is given in reference 3g. User requirements were further evaluated by TRADOC during the preparation of the Mission and Performance Envelopes using the approved Middle East I and II and European I scenarios.

(1) Independent studies conducted for DOD have projected serious consequences for an otherwise successful US force when faced with positive, aggressive enemy EW actions. An accurate means to quantify the impact which sophisticated EW will play in the dynamic battlefield of the future has not been developed. (See Paragraph 4c, Annex D of Appendix I, TOD.) An enemy can be expected to attempt destruction of critical communications, which are located through direction finding techniques, or employ jamming to isolate friendly elements from higher echelon command and control activities. This requires serious consideration be given to circumventing the EW threat through ECCM hardware techniques built into each SINCGARS-V radio.

(2) Radios of each alternative may be modified or designed to accommodate a steerable null antenna processor (SNAP). A discussion of the various SNAP's is contained in paragraph 3c(2) of Appendix II, TOA. While these ECCM hardware techniques provide varying degrees of protection against a jamming threat, they offer virtually no protection against enemy direction finding.

(3) Further improvements in ECCM protection can be achieved in the SINCGARS-V radio by utilizing frequency hopping type modulation. This technique spreads the transmitter's radiated energy over a wide band of frequencies in a pseudorandom hopping fashion. Discussions of the potential usefulness of frequency hopping are contained in Annex D of Appendix I, TOD, and paragraph 3c(3) of Appendix II, TOA. Frequency hopping is feasible only with Alternatives #3 and #4. In conjunction with frequency hopping, a SNAP can provide these alternatives with additional ECCM protection. The application of either ECCM technique will result in the same cost differential for both Alternatives #3 and #4.

e. Industrial and Technology Base. An assessment of the capability for industry to continue economical support of the current family of radios is at Annex C. The industrial base to economically support the technology used in the current family of radios will last until approximately 1990, and then only if this base is subsidized by the continued procurement of these radios. If no procurements are made beyond those presently planned, the industrial base for the current inventory of radios will dissipate about 1985.

4. SUMMARY. The TRADOC and DDI evaluation models provide reasonable insight for comparison of alternative performance. The Comptroller of the Army recommended costs for each alternative, coupled with the other cost alternatives, provide a measure of expected costs associated with each alternative.

a. Retention of Alternative #1 as the principal method for exercise of command and control subjects the Army to the risk of having a deployed combat net radio, equipped with only a limited and relatively expensive ECCM capability (i.e., a SNAP) which will be highly vulnerable to intercept and enemy direction finding and subsequent destruction by hostile action. Continued procurement and retention of the current family of radios will become increasingly costly. As the technological base continues to shift, the Army must assume the total burden of the support of obsolete technology.

b. Since feasible ECCM techniques can be had for essentially the same cost in either Alternative #3 or #4, there is no advantage in pursuing Alternative #3 further.

c. Compared to all other candidates, the relative worth of Alternative #4, considered across its range of values, provides a strong case for proceeding with the initiation of its development program. This conclusion is reinforced further by the cost and performance penalty which the Army would suffer should a radio development proceed which does not capitalize upon the sharing of functions with the COMSEC module. While the capability of the recommended alternative to counter the EW threat and enhance the probability of communications is not quantifiable at present, this alternative provides the most rational approach to insuring the commander a good capability for direct control of his combat resources to influence the course of the battle.

5. RECOMMENDED APPROACH. Initiate Advance Development of a new SINCGARS-V radio (Alternative #4) to provide a cost effective solution to the user's operational requirements.

TABLE IV-1  
FIGURE OF MERIT SUMMARY  
(Developed by TRADOC COEA)

<u>CONFIGURATION</u>	<u>BASIS FOR RANKING</u>	<u>ALTERNATIVES</u>			
		<u>#1</u>	<u>#2</u>	<u>#3</u>	<u>#4</u>
MANPACK (29% of IIQ*)	Performance	13.84	14.36	16.43	17.50
	Weighted Performance	502.60	525.81	675.96	700.65
	MPE**	12.97	13.06	15.39	16.11
	Weighted MPE	471.87	480.55	630.69	657.12
VEHICULAR with 40-watt Power Amplifier (54% of IIQ)	Performance	13.93	15.58	16.89	17.61
	Weighted Performance	592.51	637.29	693.70	725.45
	MPE	11.87	13.72	15.15	16.11
	Weighted MPE	525.32	571.06	614.66	663.70
AIRCRAFT (17% of IIQ)	Performance	15.10	16.52	16.85	17.83
	Weighted Performance	643.25	668.70	673.13	707.68
	MPE	12.46	14.57	14.34	15.87
	Weighted Performance	570.32	626.82	616.55	655.36

\* IIQ - Initial Issue Quantity

\*\* MPE - Mission and Performance Envelopes

TABLE IV-2

## RELATIVE PERFORMANCE INDICES

(TRADOC Figures of Merit Normalized to Alternative #1)

CONFIGURATION	BASIS OF RANKING	ALTERNATIVES			
		#1	#2	#3	#4
MANPACK	Performance	1	1.04	1.19	1.26
	Weighted Performance	1	1.05	1.34	1.39
	MPE	1	1.01	1.19	1.24
	Weighted MPE	1	1.02	1.34	1.39
VEHICULAR	Performance	1	1.12	1.21	1.26
	Weighted Performance	1	1.08	1.17	1.22
	MPE	1	1.16	1.28	1.36
	Weighted MPE	1	1.09	1.17	1.26
AIRCRAFT	Performance	1	1.09	1.12	1.18
	Weighted Performance	1	1.04	1.05	1.10
	MPE	1	1.17	1.15	1.27
	Weighted MPE	1	1.10	1.08	1.15

TABLE IV-3

COMPOSITE RELATIVE PERFORMANCE INDICES\*

<u>BASIS FOR RANKING</u>	<u>ALTERNATIVE #1</u>	<u>ALTERNATIVE # 2</u>	<u>ALTERNATIVE #3</u>	<u>ALTERNATIVE #4</u>
Performance	1	1.09	1.19	1.25
Weighted Performance	1	1.06	1.20	1.25
MPE	1	1.12	1.23	1.31
Weighted MPE	1	1.07	1.20	1.28

\* Based on percentage of equipment deployed for all configurations.

TABLE IV-4

UTILITY SUMMARY

(Developed by DDI COEA)

<u>MAJOR DIMENSION OF VALUE</u>	<u>ALTERNATIVE #1</u>	<u>ALTERNATIVE #2</u>	<u>ALTERNATIVE #3</u>	<u>ALTERNATIVE #4</u>
Operational Acceptability	0.6863	0.7267	0.7430	0.7057
Technical System Utility	0.3399	0.3858	0.6503	0.6450
Overall Military Value	0.5131	0.5563	0.7067	0.7204

TABLE IV-5

RELATIVE UTILITY SUMMARY

(Data of Table IV-4 Normalized to Alternative #1)

	<u>ALTERNATIVE #1</u>	<u>ALTERNATIVE #2</u>	<u>ALTERNATIVE #3</u>	<u>ALTERNATIVE #4</u>
Operational Acceptability	1	1.06	1.08	1.16
Technical System Utility	1	1.14	1.91	1.90
Overall Military Value	1	1.08	1.38	1.40



TABLE IV-6

SUMMARY COST ESTIMATES  
(FY 76 Constant \$, Millions)

ALTERNATIVE	RESEARCH & DEVELOPMENT		INVESTMENT		OPERATING & SUPPORT		TOTAL	
	LCCE/ BCE	IPCE	LCCE/ BCE	IPCE	LCCE/ BCE	IPCE	LCCE/ BCE	IPCE
#1	0	0	226.6	245.9	158.0	447.0	384.6	692.9
#2	4.1	4.2	490.0	613.6	147.2	530.0	641.3	1147.8
#3	12.3	17.9	480.9	567.9	170.2	280.2	663.4	866.0
#4	42.0	33.2	435.7	497.3	121.0	240.9	598.7	777.1

TABLE IV-7

COMPTROLLER OF THE ARMY RECOMMENDED COST POSITION  
(FY 76 Constant \$, Millions)

ALTERNATIVE	RESEARCH & DEVELOPMENT	INVESTMENT	OPERATING & SUPPORT	TOTAL
#1	0	226.6	318.0	544.6
#2	5.0	490.0	335.0	830.0
#3	17.0	480.9	155.0	652.9
#4	42.0	435.7	133.0	610.7

TABLE IV-8

RELATIVE COST COMPARISON  
(Data of Table IV-7 Normalized to Alternative #1)

ALTERNATIVE	LCCE/BCE	IPCE	COA
#1	1	1	1
#2	1.67	1.66	1.52
#3	1.72	1.25	1.20
#4	1.53	1.11	1.12

TABLE IV-9  
RELATIVE WORTH MATRIX  
(Data Normalized to Alternative #1)

<u>ALTERNATIVE</u>	<u>TRADOC COEA*</u>			<u>DDI COEA</u>		
	<u>BCE</u>	<u>IPCE</u>	<u>COA</u>	<u>BCE</u>	<u>IPCE</u>	<u>COA</u>
#1	1.0	1.0	1.0	1.0	1.0	1.0
#2	0.64	0.64	0.70	0.65	0.65	0.71
#3	0.70	0.96	1.0	0.80	1.10	1.15
#4	0.84	1.15	1.14	0.92	1.26	1.25

\*Weighted MPE's were used to derive relative worth.

TABLE IV-10  
COMPTROLLER OF THE ARMY APPROVED  
15-YEAR COMSEC EQUIPMENT LIFE CYCLE COST ESTIMATES, 100% COMSEC  
(FY 76 Constant \$ Millions)

<u>ALTERNATIVE</u>	<u>RESEARCH &amp; DEVELOPMENT</u>	<u>INVESTMENT</u>	<u>OPERATING &amp; SUPPORT</u>	<u>TOTAL</u>
#1	1	835	66	902
#2	1	835	66	902
#3	1	798	66	865
#4	1	591	57	649

OTE: Each alternative includes the programmed buy for 44,240 VINSONS. VANDAL COMSEC devices complete the AAO. Alternatives #1, #2 and #3 use VANDAL Appliques; Alternative #4 uses VANDAL TOP HAT.

TABLE IV-11  
RELATIVE WORTH FOR 100% COMSEC  
(Using COA Recommended Costs)

<u>ALTERNATIVE</u>	<u>TRADOC COEA</u>	<u>DDI COEA</u>
#1	1	1
#2	0.89	0.9
#3	1.14	1.31
#4	1.47	1.61



ANNEX A (TRADOC COMBAT DEVELOPMENTS STUDY FINAL REPORT) TO APPENDIX IV (COST AND OPERATIONAL EFFECTIVENESS ANALYSIS)

This Annex contains a summary of the TRADOC COEA of the SINCGARS-V study on pages IV-A-6 through IV-A-12. The TRADOC COEA was distributed separately as indicated in the cover letter below; it has been omitted here because of its size.



DEPARTMENT OF THE ARMY  
HEADQUARTERS UNITED STATES ARMY TRAINING AND DOCTRINE COMMAND  
FORT MONROE, VIRGINIA 23651

ATCD-SC-E

12 September 1975

SUBJECT: Combat Developments Study Final Report: Cost and Operational Effectiveness Analysis (COEA) for the VHF/FM Portion of the Single Channel Ground and Airborne Radio Subsystem (SINCGARS-V)

HQDA (DAMO-SGTF)  
WASH DC 20310

1. Reference, Letter, DAMO-SGTF, HQDA, Combat Developments Study Directive: Cost and Operational Effectiveness Analysis (COEA) for the VHF/FM Portion of the Single Channel Ground and Airborne Radio Subsystem (SINCGARS-V), 25 February 1975.
2. The SINCGARS-V COEA Final Report (inclosure 1) is submitted in response to the referenced study directive.
3. This headquarters has reviewed the Final Report and concurs in the conclusions and recommendations.
4. It should be noted that the cost and performance findings unquestionably rank alternatives 3 and 4 over alternatives 1 and 2. However, the difference between the performance of alternatives 3 and 4 are significantly influenced by the qualitative measures used where quantitative measures of performance were not available. An analysis of the quantitative differences between alternatives 3 and 4 indicated that the margin between the two was very narrow. A further subjective analysis of alternatives 3 and 4, based on the final draft Trade Off Determination, Trade Off Analysis, and Best Technical Approach, did support the conclusion that alternative 4 is the preferred alternative for further development.
5. Follow-on actions will address the development of measures of effectiveness and the elimination of qualitative measures from any aggregation of the performance figures of merit.

12 September 1975

ATCD-SC-E

SUBJECT: Combat Developments Study Final Report: Cost and Operational Effectiveness Analysis (COEA) for the VHF/FM Portion of the Single Channel Ground and Airborne Radio Subsystem (SINCGARS-V)

6. The study plan indicated that a 16/8 division force structure would be considered in the COEA. The AAO associated with the current force structure, as provided by ECOM in their LCCO computations, was used to develop a comparative base. The 125% AAO investigated in the sensitivity analysis closely approximates the 16/8 division force and provides an estimate of costs to support the larger force.

7. This action is identified with TRADOC ACN 23362.

1 Incl  
as

*W. H. Vinson, Jr.*  
W. H. VINSON, JR.  
Major General, GS  
Deputy Chief of Staff  
for Combat Developments

CF: w incl  
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ATCD-SC-E

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Comdt

USAIS, ATTN: ATSH-CTD-MS

USAES, ATTN: ATSE-CTD

USAADS, ATTN: ATSA-CTD

USAIMA, ATTN: ATSU-CTD

USATSCH, ATTN: ATSP-CTD

USAMPS, ATTN: ATSJ-CTD

USAQMS

USAFAS, ATTN: ATSF-CTD

DIRNSA ATTN: S45

CINCUSAREUR, ATTN: AEAGE/ATFE-LO-AE (TRADOC LO) - 2



ACN 22362

AD

# **TRASANA**

**COST AND OPERATIONAL EFFECTIVENESS ANALYSIS 1-75**

## **SINGLE CHANNEL GROUND AND AIRBORNE RADIO SUBSYSTEM (VHF/FM)**

**VOLUME I**

**SEPTEMBER 1975**

### **DISTRIBUTION STATEMENT**

Transmittal of this document outside  
the Department of Defense must have  
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**DEPARTMENT OF THE ARMY  
US ARMY TRADOC SYSTEMS ANALYSIS ACTIVITY  
WHITE SANDS MISSILE RANGE  
NEW MEXICO 88002**

Incl



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# **TRASANA**

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## SUMMARY

### PURPOSE

This cost and operational effectiveness analysis (COEA) documents the results of a study that was made to determine which of four alternatives was the most cost and operational effective VHF/FM combat net radio subsystem. The alternatives are defined in the SINGARS-V\* Tradeoff Analysis and Tradeoff Determination.

### BACKGROUND

The capability of the Army to provide integrated and secure or securable VHF/FM combat net radio communications is deficient in the areas of size, weight, reliability/availability/maintainability (RAM), communications security (COMSEC), electronic counter-countermeasures (ECCM), electromagnetic capability (EMC), and nuclear and nonnuclear hardening. To correct these deficiencies, the SINGARS-V Required Operational Capability (ROC) was approved by the Department of the Army prior to the implementation of AR 71-9. It provides a basis for the completion of advanced development programs.

The SINGARS-V Special Task Force requested the assistance of US Army Training and Doctrine Command (TRADOC) in December 1974; a study directive was issued by Department of the Army on 25 February 1975. The subsequent study plan was approved 6 May 1975.

The SINGARS-V program is a follow-on to the development program of the Tactical Radio Communications System. The proposed alternatives range from the conceptual phase to the subsystem advanced development category of the validation phase.

This study provides an initial COEA which takes the place of the preliminary appraisal for support of a letter of agreement. Preliminary appraisals are a requirement of TRADOC Regulation 11-8.

### ASSUMPTIONS

Relative to this study the following were assumed:

- a. The results of the Integrated Tactical Communications System (INTACS) study will not invalidate recommendations of this COEA.

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\*Single channel ground and airborne radio subsystem, VHF/FM

b. The radio wire integration (RWI) approach selected by INTACS will not invalidate the final candidate that results from this COEA.

c. The basis of issue (BOI) for the recommended candidate will be the same as the BOI for the current family of VHF/FM combat net radios.

#### ALTERNATIVES

The alternatives for the VHF/FM combat net radio subsystems are as follows:

a. Retain the current VHF/FM combat net radios and incorporate planned and essential product improvements. (This alternative is the baseline against which other alternatives will be compared.)

b. Product improve the current VHF/FM combat net radios.

c. Replace the current VHF/FM family with the AN/VRC-78 radio set.

d. Replace the current VHF/FM family with a new combat net radio.

#### METHODOLOGY

Basically, the methodology, as outlined in the study plan, was structured as follows:

**Effectiveness Investigation.** An operational effectiveness model is not available for use in this COEA. In lieu of a classical effectiveness methodology, the analytical approach centered on performance of alternatives.

**Measure of Performance Development.** Critical performance areas were defined and performance parameters were derived to describe these areas. A hierarchy of measure of performance (MOP) descriptors was developed in the broad areas of operability, dependability, and physical characteristics.

**Derivation of Functional Relationships.** Mathematical models which functionally relate the MOPs were derived to produce a quantified assessment of performance. When a mathematical model could not be developed or supported, a qualitative assessment was made and a quantified value of this assessment was derived.

**Methodology Testing.** The analytical methodology was tested on data input of the United States AN/VRC-43 and the British VK/VRC-353. Results were in consonance with user expectations and indicated that the analytical methodology was technically sound.

**Performance Analysis.** A sensitivity analysis was conducted to (1) demonstrate that equations (mathematical models) respond to changes in the

input data, (2) isolate critical input parameters, and (3) demonstrate that aggregation techniques do not destroy the objective analysis.

Life Cycle Cost of Ownership Evaluation. The life cycle cost of ownership (LCCO) evaluation reflected the relative cost of ownership for each alternative. It was centered on the evaluation of the input cost data and development of analytical schemata which allowed for analyses (primarily in the areas of maintenance and procurement costs) and changes in the COMSEC configurations.

Force Implication Assessment. This assessment identified, analyzed, and quantified the resource implication in deployment of a particular SINGARS-V alternative. Data and analytical techniques inherent in the Force Cost Information System (FCIS) and Force Stratification System (FSS) were utilized.

Rank Ordering. Relative rankings of the alternatives were based on the achieved performance figures of merit (FOM) in the following categories:

- . Performance
- . Weighted performance
- . Mission performance envelope (MPE) (performance compared to requirements)
- . Weighted MPE

Cost Performance Analysis. Relative worth measures were developed for each alternative based on weighted-nonweighted performance per given dollar. Alternative MPE values and force implication assessments were then integrated into the measures to select the dominant alternative.

#### ANALYSIS

The analysis addressed three general areas: performance, cost, and rank sensitivity.

Performance analysis was accomplished for the manpack, vehicular, and airborne configurations. It considered performance alone, performance compared with the user-provided MPEs, weighted performance (inclusion of user-provided utiles), and weighted MPE. Alternative 4 - deployment of a new combat net radio - was the dominant system based on the calculated FOM for each candidate system.

Cost analysis was based on LCCO and force implications. The study conducted in accordance with AR 37-18, MIL-STD 881, and ECOMP 11-4, Volume 7,



used a model developed by Communications/Automatic Data Processing Laboratory. The cost analysis revealed that alternative 1 — retain the current VHF/FM combat net radios and incorporate planned and essential product improvement — is the least expensive alternative; alternative 4 was the next least expensive. The rank sensitivity analysis was based on performance, utile allocation, aggregation, and cost.

Performance sensitivity revealed the following:

- a. The MOPs were sensitive to all input parameters except receiver sensitivity and noise figure for the case that was examined.
- b. Critical parameters which have the most impact on the MOP were identified and are listed in order of relative impact.
- c. The additive, equal weight FOM is sensitive to the input parameters.

Utile allocation sensitivity revealed that by varying the utile allocation by one performance factor at a time within a calculated spread, no change in the rank ordering of alternatives was possible in any configuration.

Aggregation sensitivity revealed that the percentages of agreement of the various forms with the additive forms vary inversely with the range of the input parameters which describe the alternatives.

For LCCO sensitivity, rank ordering to 125 percent and 75 percent variations in Army acquisition objective (AAO) was determined and Alternative 1 remained the least expensive for each variation.

#### RELATIVE WORTH

The individual performance of each alternative in the different configurations — manpack, vehicular, and airborne — were summed to obtain an overall FOM. The weighted performance scores were considered the best

Weighted Performance Totals					
Comparison	Alternative				
	1	2	3	4	5
Perf	42.87716	46.45199	50.16316	48.59485	52.94108
Wt Perf	1738.359	1831.8	2042.779	1988.02	2133.775
MPE Perf	37.30948	31.35309	44.87031	43.43102	48.08956
Wt MPE Perf	1567.513	1678.421	1861.894	1813.636	1976.178
Rank Order	5	4	2	3	1
*25 khz					
**50 khz					

indicators of alternative performance. A performance threshold was developed using the scenario developed MPE and utility weights. This threshold establishes the minimum acceptable performance level. As

<u>RELATIVE WORTH COMPARISON</u>					
<u>Alternative</u>	<u>Total Wt Performance</u>	<u>LCCO (m)</u>	<u>Relative Performance</u>	<u>Relative Cost</u>	<u>Relative Worth</u>
1	1738.359	387.0	-	-	-
2	1831.8	685.8	1.0	1.0	1.0
3 (25 kHz)	2042.779	668.4	1.1152	.9746	1.1443
3 (50 kHz)	1988.02	668.4	1.0853	.9746	1.1136
4	2133.775	586.7	1.1649	.8555	1.3617

stated in the DA-approved ROC and validated in the scenario analysis, Alternative 1 does not meet the minimum acceptable performance level and was not considered in the calculations of relative worth. The relative worth of each of the remaining alternatives was calculated by the equation:

$$RW = \frac{\frac{\text{Performance of Alternative}}{\text{Performance of Basecase}}}{\frac{\text{LCCO of Alternative}}{\text{LCCO of Basecase}}}$$

Alternative 4 provided the best relative worth and is the most cost and operationally effective alternative.

#### SUBJECTIVE FACTORS

Those areas in which subjective factors have a potential impact on the conclusions of this analysis were assessed. The results were as follows:

The impact of the scenario which describes the forces, terrain, type conflict, and threat fall into two areas: MPE and the evaluation of environment-sensitive MOP. Analysis reveals that the MPE which would be developed should encompass the probable (lower limit) and possible (upper limit) operational requirements. Furthermore, the MOPs are sensitive to scenario changes, but the relative rankings of the alternatives are not affected by these changes.

The cost and performance data that were provided indicated no change from current procedures in maintenance and other logistical support measures.

Operationally, the principal impact of improved failure rates and repair times of the alternatives is a significantly improved operational availability for the individual user. This means that a tactical leader or firepower element retains a radio communications capability which might otherwise be lost due to maintenance failure. In turn, better maneuver capability and increased firepower control is provided the commander. Therefore, the impact of improved operational availability is highly significant on the battlefield even though the actual impact cannot be measured in terms of firepower and maneuver.

The MOPs which addressed individual and collective training were not used in the rankings of the four alternatives. A review of the tradeoff analysis and tradeoff determination indicated no expected change in requirements for any of the alternatives. COMSEC and ECCM were the only areas where performance can be improved by increased training.

In terms of flexibility, Alternative 4 — deployment of a new combat net radio — is enhanced by its adaptability to a design which would incorporate the improved ancillaries. No constraints would be imposed by add-on interface adapters and no compromises would be required in the ancillary design in order to integrate with a fixed radio design.

#### FINDINGS

The relative rankings achieved by the alternatives through considerations of performance, LCCO, user requirements, and relative worth are summarized as follows:

Alternative	Relative Rankings			
	Performance	LCCO	User Requirements	Relative Worth
1	4	1	4	-
2	3	4	3	3
3	2	3	2	2
4	1	2	1	1

#### CONCLUSIONS

On the basis of the analysis, the following conclusions were derived:

##### Performance

- a. Alternative 4—a new combat radio using advanced technology — will perform better than the other three alternatives.
- b. Alternative 4 will better satisfy stated user requirements.

#### Cost Analysis

- a. Alternative 1 - the current VHF/FM net radio subsystem - is least costly.
- b. The assessment of force implications with respect to the deployment of a particular alternative could not be translated to force unit costs since the required level of detail was not available for this initial COEA.

#### Relative Worth Analysis

- a. The best performance per dollar values was provided by Alternative 4.
- b. Alternative 4 is the preferred alternative based on its capability to meet user requirements.
- c. Follow-on actions can be used to reduce uncertainty of performance factors.

#### RECOMMENDATIONS

Recommendations are as follows:

- a. Alternative 4 be accepted as the preferred alternative for further development.
- b. Follow-on actions identified in Appendix V be accomplished for inclusion in the COEA update for ASARC II.

ANNEX B (CONTRACTOR DEVELOPED COEA) TO APPENDIX IV (COST AND OPERATIONAL EFFECTIVENESS ANALYSIS)

This Annex contains a summary of the DDI COEA of the SINCGARS-V study. This COEA study has been published as two separate documents; they have been omitted here because of their size.

A Technical Report

**SINGLE CHANNEL GROUND AND AIRBORNE  
RADIO SYSTEM (SINCGARS) EVALUATION MODEL**

by

Dr. J.O. Chinnis, Dr. C.W. Kelly III  
Mr. R.D. Minckler, Dr. M.F. O'Connor

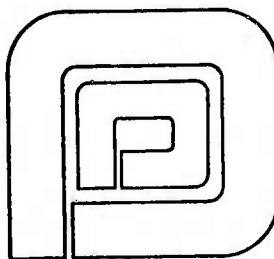
Sponsored by

The Director, SINCGARS Special Task Force  
Office of the Deputy Chief of Staff for Operations and Plans  
Department of the Army

and

The Defense Advanced Research Projects Agency  
Contracts N00014-75-C-0426 and N00014-73-C-0149

September 15, 1975



**DECISIONS and DESIGNS, INC.**

Suite 100, 7900 Westpark Drive  
McLean, Virginia 22101  
(703) 821-2828

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Department of the Army, The Defense Advanced Research Projects Agency, or the U.S. Government.

## SUMMARY

Introduction. This report describes the development, validation, and utilization of a multi-attribute utility model for use by the SINCGARS Special Task Force (STF) in evaluating the military utility of a series of alternative radio systems. The model was programmed to be interactive and was made available to the SINCGARS staff to allow further analyses.

Background and Approach. The SINCGARS Special Task Force was established by the Army Chief of Staff for the purpose of defining and recommending an optimum solution for meeting the Army's requirement to ensure that a prescribed level of suitable Very High Frequency (VHF)-Frequency Modulated (FM) Combat Net Radios (CNRs) will be available in the Army inventory in the post-1980 time frame. To this end, the SINCGARS STF defined the following four alternative courses of action for comparison/evaluation with respect to satisfying the Army's requirements for CNRs:

- Alternative 1. Retain the current VHF-FM CNRs (which consist of three families of radios) with minor product improvements.
- Alternative 2. Develop and ultimately procure a product-improved version of the current VHF-FM combat net radios that will operate with a 25 KHz channel spacing.
- Alternative 3. Continue development and ultimately procure Radio Set, An/URC-78.
- Alternative 4. Develop and ultimately procure a new family of VHF-FM combat net radios.

The objective of the research described in this report was to develop and test a multi-attribute utility model to be used to assist the SINCGARS STF of the U.S. Army in evaluating the military utility of alternative Combat Net Radio configurations. Of particular importance during the development of the model was the need to provide an analytic tool which would accept "last minute" changes in data and would also enable a user to conduct "what if" analyses on an interactive basis. A multi-attribute utility model was developed which would systematically quantify the utility of alternative radio systems. The model utilizes as inputs the technical performance characteristics of a radio system.

The results indicate that Alternatives 3 and 4 are superior to Alternatives 1 and 2, mainly due to differences in technical system utility. Further examination of the results indicated that this superiority with respect to technical system utility is due to a significant improvement with respect to both dependability and technical performance. Technical system utility is a multiplicative combination of these two factors.

Alternatives 1 and 2 are both far superior to the Korean War System (KWS). Alternative 2, however, is only slightly superior to Alternative 1 with respect to both technical system utility and operational acceptability.

The foregoing results were based upon the information which was available with regard to the various alternative radio systems. The flexible structure of the SINCGARS Evaluation Model, however, has enabled the SINCGARS STF to continue to use the model:

- With new or modified input data.
- To conduct "what if" analyses on an iterative, interactive basis in response to queries that have been received.

In so doing, the SINCGARS STF has attained an increasingly better understanding of all of the factors involved in the evaluation of the alternative systems and a greater degree of confidence in the recommendations which have been made based upon the use of the model.

Methodological Implications. The following two additional observations are also important from the standpoint of decision analytic theory:

- The evaluation of alternative systems is very closely related to system design, so the evaluation model must be very flexibly structured with respect to possible changes in inputs in order to permit meaningful "what if" analyses. For example, the range of a technical performance characteristic over which a utility function is assessed should not be the entire physical performance range of a general system, for this will cause the model to be quite insensitive. If specific alternatives which will not change are to be evaluated for purpose of choosing among them, the range of a performance characteristic should be the range for the alternatives under consideration. However, when the designs of developmental or conceptual systems are being evaluated, then the range of a technical performance characteristic over which a utility function is assessed should reflect the minimum feasible to the maximum feasible performance range of those systems.



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- Close attention must also be given to the definition of scenarios as conditioning variables in the evaluation of alternative systems. The scenarios should be so defined that not only will they be representative of the situations in which the alternatives will operate and thus permit the assessment of the expected utilities of all of the alternative systems, but also they must serve to discriminate clearly among the alternative systems. These goals are not usually compatible, and an in-depth analysis of which goal to pursue must be accomplished in order to decide upon the definition of scenarios.

# UNCLASSIFIED

ANNEX C (FUTURE SUPPORT OF AN/PRC-77 AND AN/VRC-12 FAMILIES OF RADIOS) TO APPENDIX IV (COST AND OPERATIONAL EFFECTIVENESS ANALYSIS)



DEPARTMENT OF THE ARMY  
HEADQUARTERS UNITED STATES ARMY ELECTRONICS COMMAND  
FORT MONMOUTH, NEW JERSEY 07703

AMSEL-RD-0

22 SEP 1975

MEMORANDUM FOR: COL THOMAS C. NELSON  
Director, SINGARS Special Task Force  
DAMO SGTF

SUBJECT: Future Support of AN/VRC-12 and AN/PRC-77

## 1. References:

a. Your telephone request to me 11 Sep 75 requesting our opinions as to when subject radio might become non-supportable.

b. Telephone conversations between yourself and personnel of the US Army Electronic Devices and Technology Lab (ECOM) above subject.

c. Our telephone conversations during week of 15 Sep 75.

2. Status of both the AN/VRC-12 and AN/PRC-77 systems with respect to future availability of parts is as follows, based on our knowledge of technology and judgement as pertains to economic factors.

(1) AN/PRC-77: This system has been redesigned, modularly, to replace germanium devices (which are in increasing short supply) with silicon devices. In fact, some modules using integrated circuits have been employed. The future availability of silicon devices has been confirmed by suppliers for a period of 10-15 years depending on economic factors such as procurement of the system and procurement of maintenance spares.

(2) AN/VRC-12: Motorola plans to discontinue production of germanium transistors. Their cut-off date for acceptance of orders is Jan 76. They grow their own material and thus must know of any large transistor buys by Oct 75 in order to make a sufficient quantity of germanium crystals to fill transistor orders anticipated to be received by Jan 76. Their production line will continue running to approximately mid-76 to complete production on orders received before the cut-off date. In view of this, two alternatives are being considered:

Strengthen America's Peace Power  
—Buy U. S. Savings Bonds

# UNCLASSIFIED

# UNCLASSIFIED

AMSEL-RD-0 22 Sep 75  
SUBJECT: Future Support of AN/VRC-12 and AN/PRC-77

(a) FY-77 and FY-78 reprocurements are possible provided the Government contracts for a "buy-out" from Motorola on those devices they produce, sufficient to supply approximately 10,000 radio sets and sufficient maintenance spares for the life of the equipment.

(b) A funded FY-76 Product Improvement Program is planned which includes the substitution of critical semi-conductors. It is anticipated that production of the improved set could begin in FY-79/80.

3. Based on our analyses it appears both the AN/VRC-12 and AN/PRC-77 systems will be supportable for 10-15 years, that is until the 1985-1990 time frame.



E. L. BOWMAN  
Colonel, SigC  
Deputy Director, RDE/L

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